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# Turbulence Kinetic Energy in the Oklahoma City Urban Environment

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Vancouver, Canada
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## Disclaimer

# TURBULENCE KINETIC ENERGY IN THE OKLAHOMA CITY URBAN ENVIRONMENT

## (as measured at a site typically downwind of the CBD)


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The pseudo-tower crane was constructed by **William Ralph** of LLNL with assistance from **Allied Steel of Oklahoma City**, **Joe Shinn** (LLNL) **Ron Pletcher** (LLNL), and **Marshall Stuart** (LLNL). The building data base was provided by **May Yuan** and **Mang Lung Cheuk** of OU.



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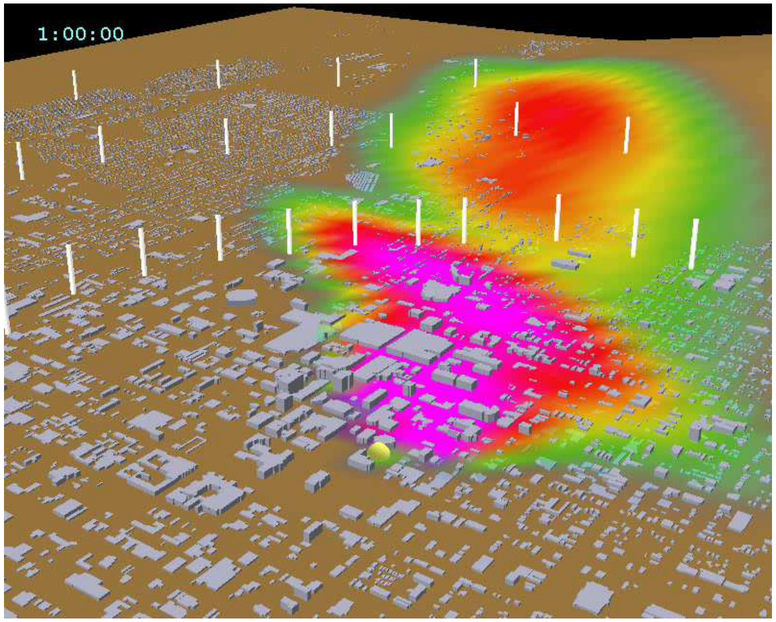
# OBSERVATIONS CAN DRIVE MODEL IMPROVEMENT

- Plume/puff urban dispersion models (i.e. QWIC-PLUME, UDM) rely on empirical generalizations of atmospheric turbulence – but which measurements are appropriate for driving these models?

- CFD models (i.e. FEM3MP, ADM, FAST3D-CT) require validation of their dynamics as well as the advection/diffusion of tracers

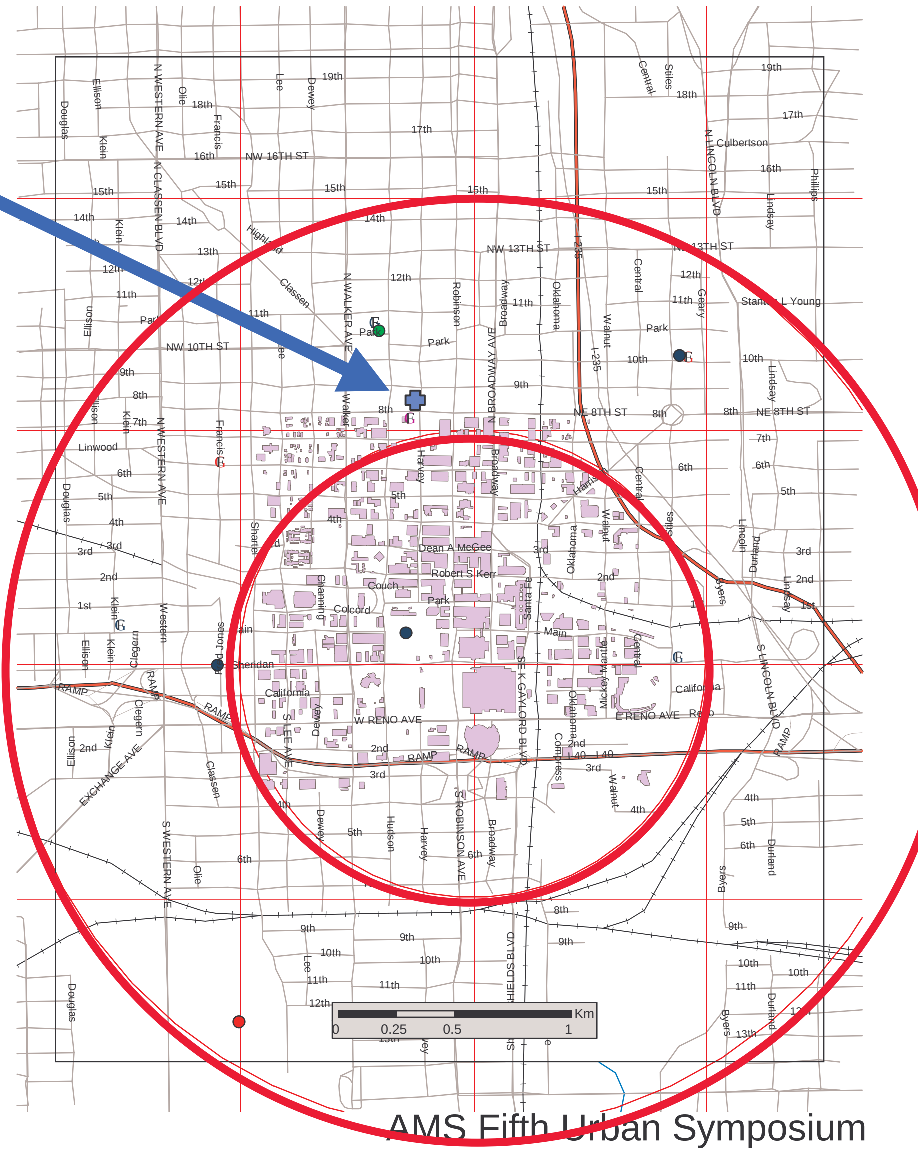



- Mesoscale models require parameterization of effects such as upwind convergence / downwind divergence, and the imbalance between TKE production and dissipation

Ø Analysis of data from a tower within the roughness sublayer of OKC can offer improved parameterizations

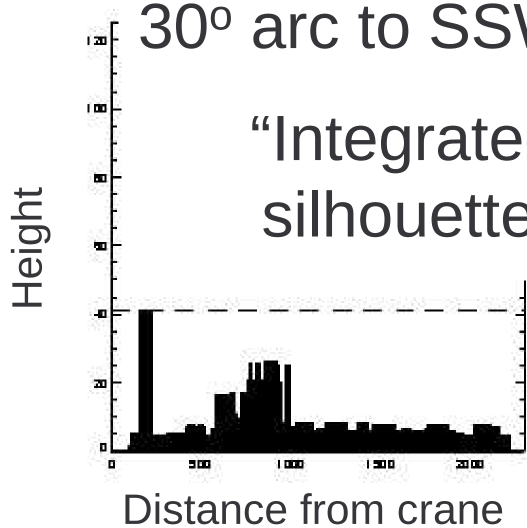
# EXPERIMENTAL CONTEXT: URBAN OKC

- **Crane located at the southwest corner of 8th and Harvey, just north of the central business district (CBD), typically downwind of the CBD**
- **Red rings mark radii of 1 and 2 km from the Westin $SF_6$ release point.**
- **Pseudo-tower constructed: top anchored to crane, bottom anchored to a massive weight to maintain tension and minimize swaying or twisting.**

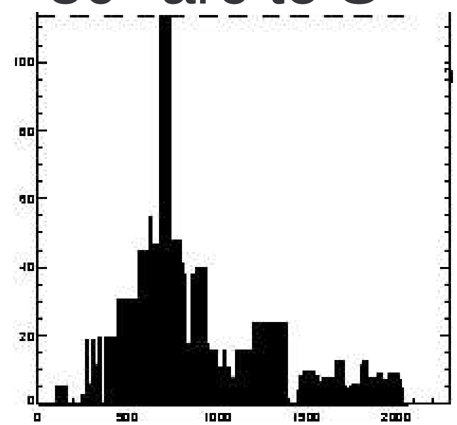


# EXPERIMENTAL CONTEXT:
# BUILDING HEIGHTS 0-2 km from the crane

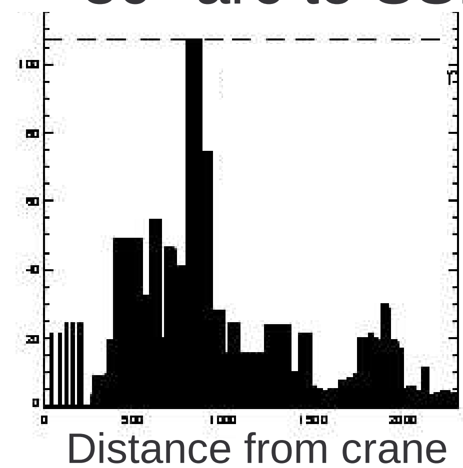
30º arc to SSW



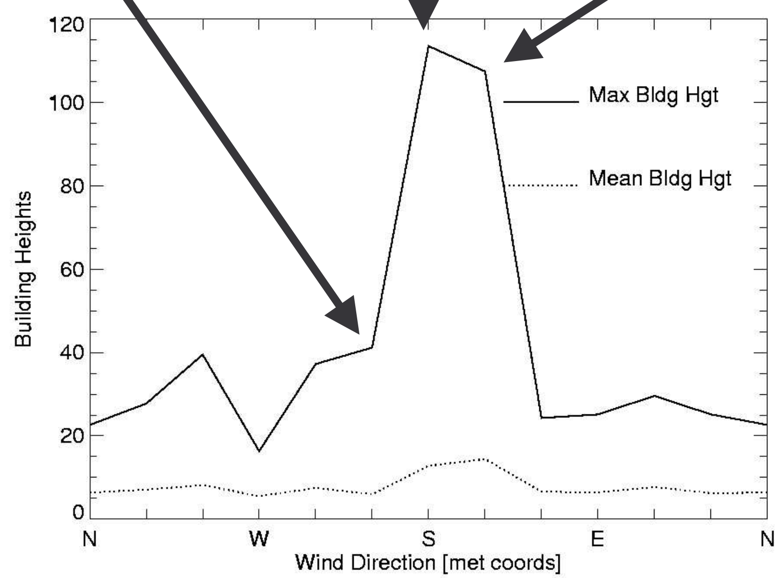

30º arc to S




30º arc to SSE

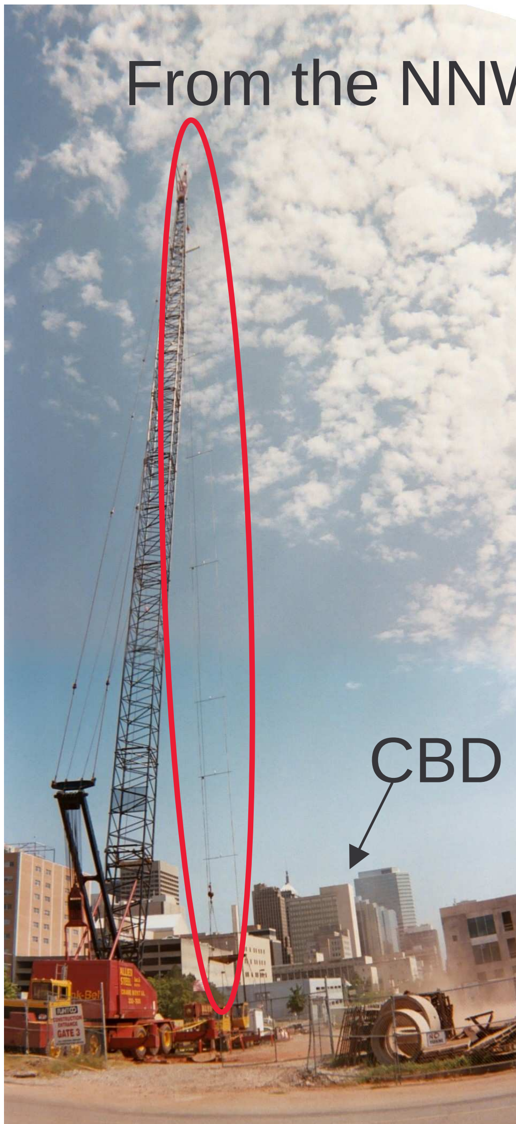



**All of OKC’s buildings taller than 40 m are S or SSE of the crane.**



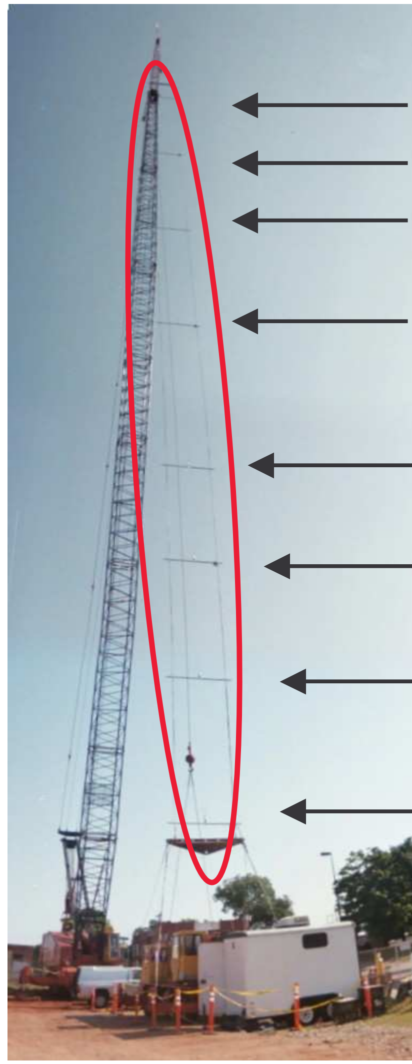

**The deepest roughness sublayer is thus found during S-ly or SSE-ly wind conditions.**

# CRANE PLATFORM ENABLED A PSEUDO-TOWER OF 8 SONIC ANEMOMETERS




DEQ

From the SW



83.2 m

69.7 m

55.8 m

42.5 m

28.3 m

21.5 m

14.6 m

7.8 m level, likely influenced by trailer

WSU operated 7 $SF_6$ intakes along the crane

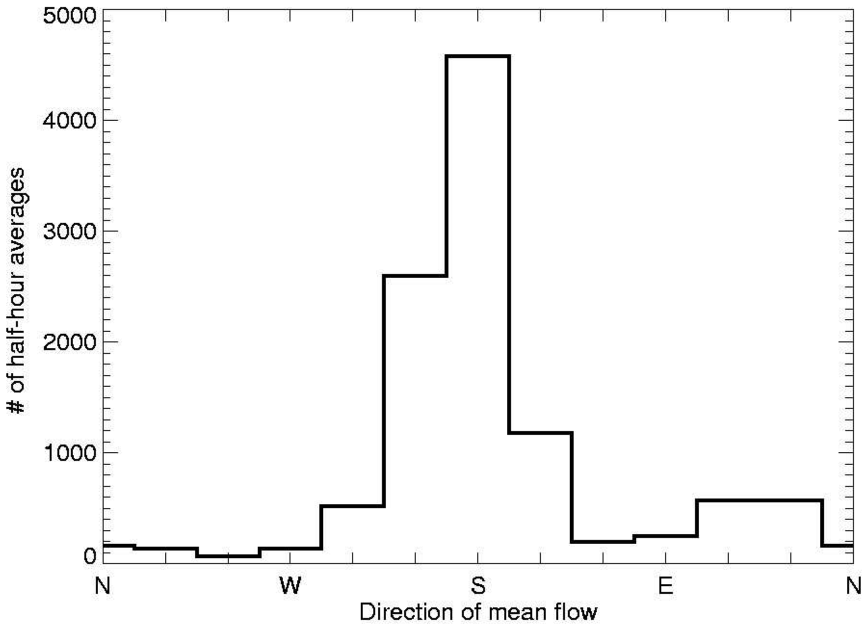
# CLOSE-UP OF THE ANEMOMETERS

- **Sonic anemometers (10 Hz R. M. Young model 81000) located at all 8 levels**
- **Lowest level data dominated by influence of trailer**

Each sonic was mounted on a 10-ft "unistrut". The span between the ½" diameter steel cables, running vertically, was 8 ½-ft.

# CRANE PSEUDO-TOWER SONIC ANEMOMETER DATASET

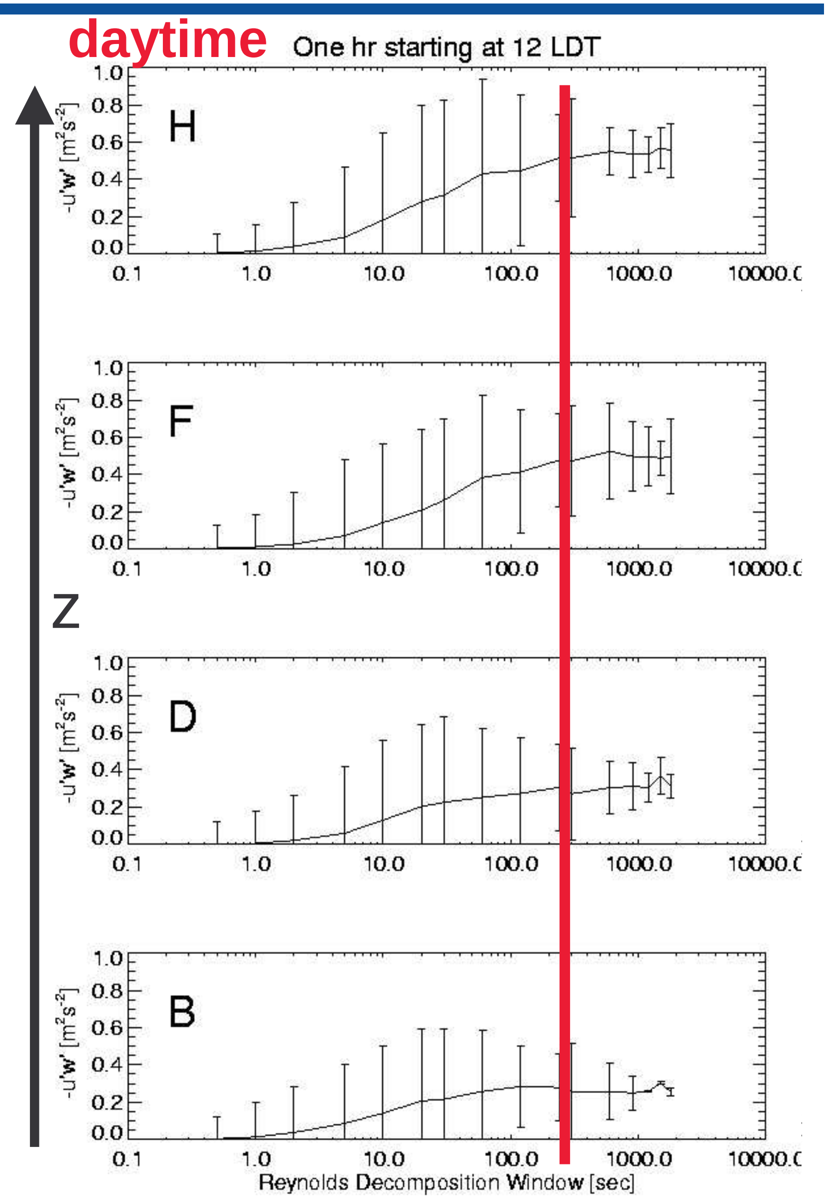
- **30 days of operations**
- **8 levels, 7.8 – 83.2 m**
- **Sonic tilt correction using planar fit method (Wilczak, Oncley & Stage, 2001 *BLM*)**
- **30 minute segments for flux and dissipation calculations – 11520 data points.**
- **Only 1000 30-min segments contaminated due to northerly flow through the crane structure.**
- **413 30-min segments eliminated due to instrument failure**
- **10107 30-min segments available for analysis**



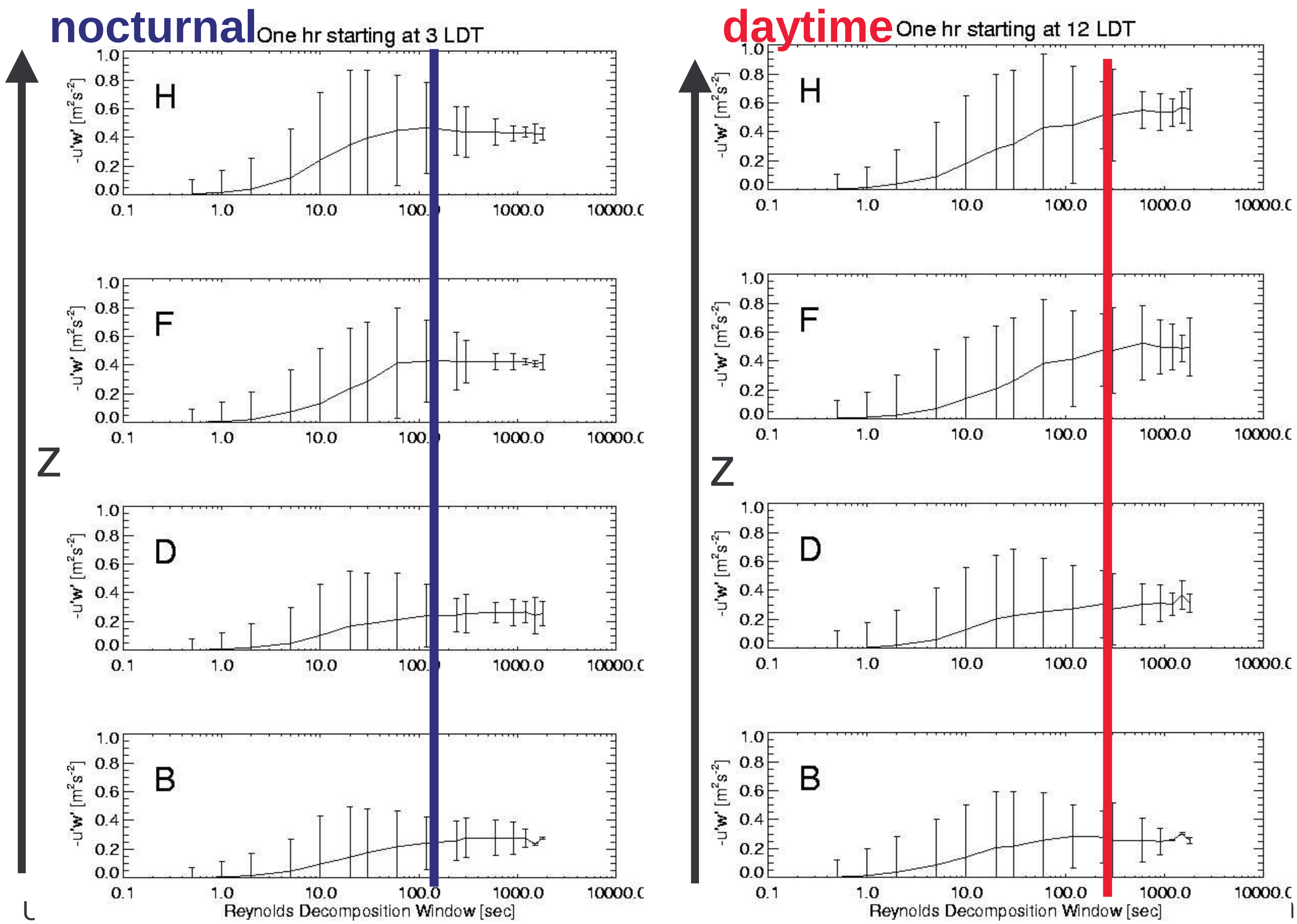

Winds were generally southerly; the maximum 30-min avg wind speed was 10.5 $ms^{-1}$.

# EXPLORING REYNOLD'S AVERAGING INTERVALS FOR FLUX CALCULATIONS

- Standard rule of thumb is 30-minutes for CBL, 10-minutes or shorter for SBL
- We explored various intervals for covariance calculations, ranging from 0.5 – 1800 sec
- JU2003 crane fluxes give consistent estimates for Reynold's averaging windows between 150 seconds and 30 minutes for both nocturnal and daytime situations



# EXPLORING REYNOLD'S AVERAGING INTERVALS FOR FLUX CALCULATIONS



# STABILITY CHARACTERISTICS OF CRANE DATA

- **Fluxes calculated over 30-minute intervals**
- **Reference temperature $T_o$ of 300 K**
- **"Neutral":**

$$-0.2 \le \frac{z}{L} \le +0.2$$

- **"Stable":**

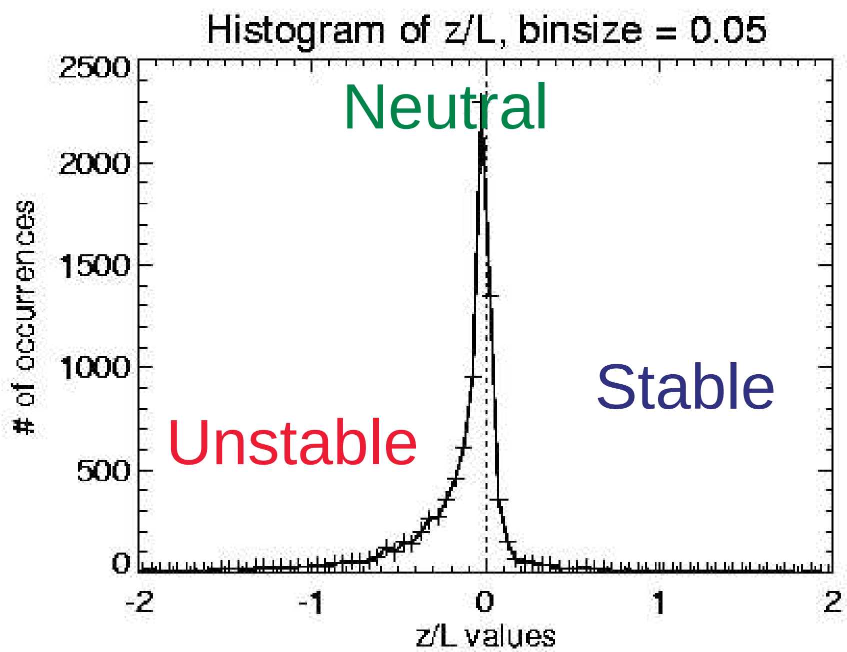
$$\frac{z}{L} \ge 0.2$$

- **"Unstable":**

$$\frac{z}{L} \le -0.2$$

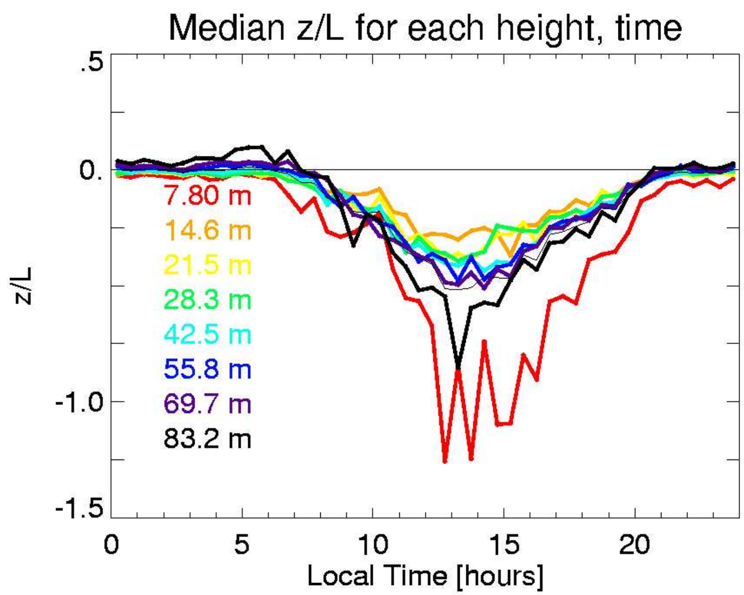
- **Neutral 60% + of the time!**

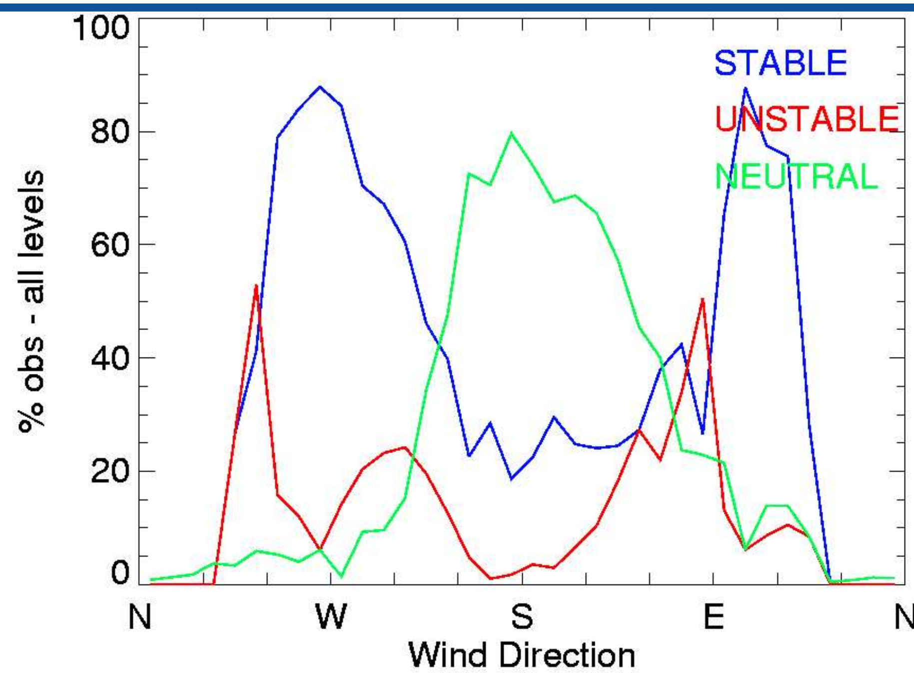
$$\frac{z}{L} = -\frac{zkg\left(\overline{w'T'}\right)}{u_*^3 T_o}$$



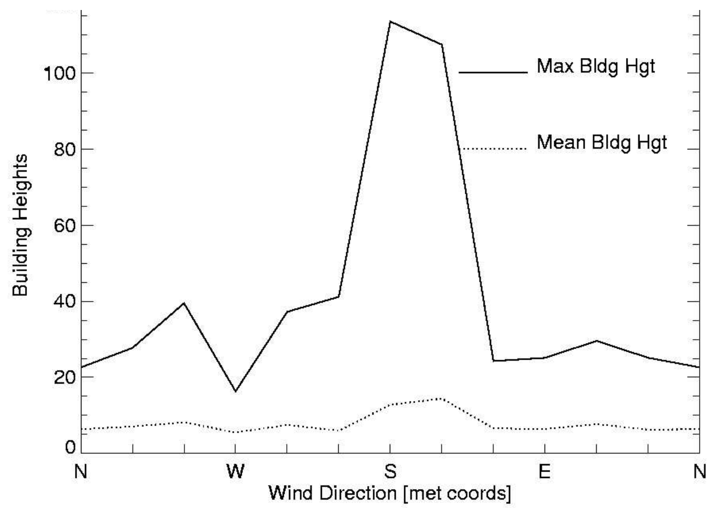
# VARIABILITY OF STABILITY

## Diurnal cycle in z/L is evident,

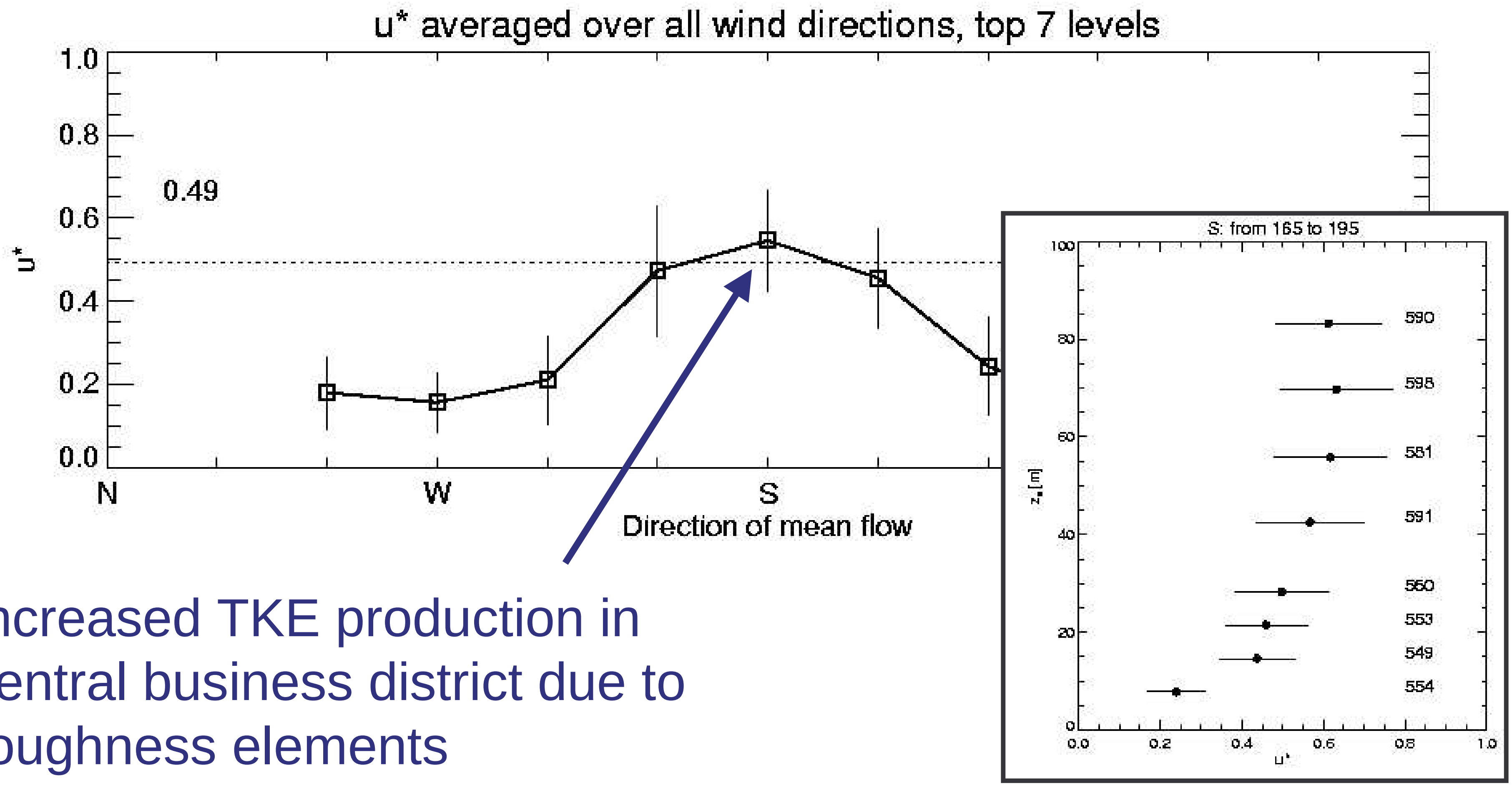



## But so is a very strong dependence on wind direction!



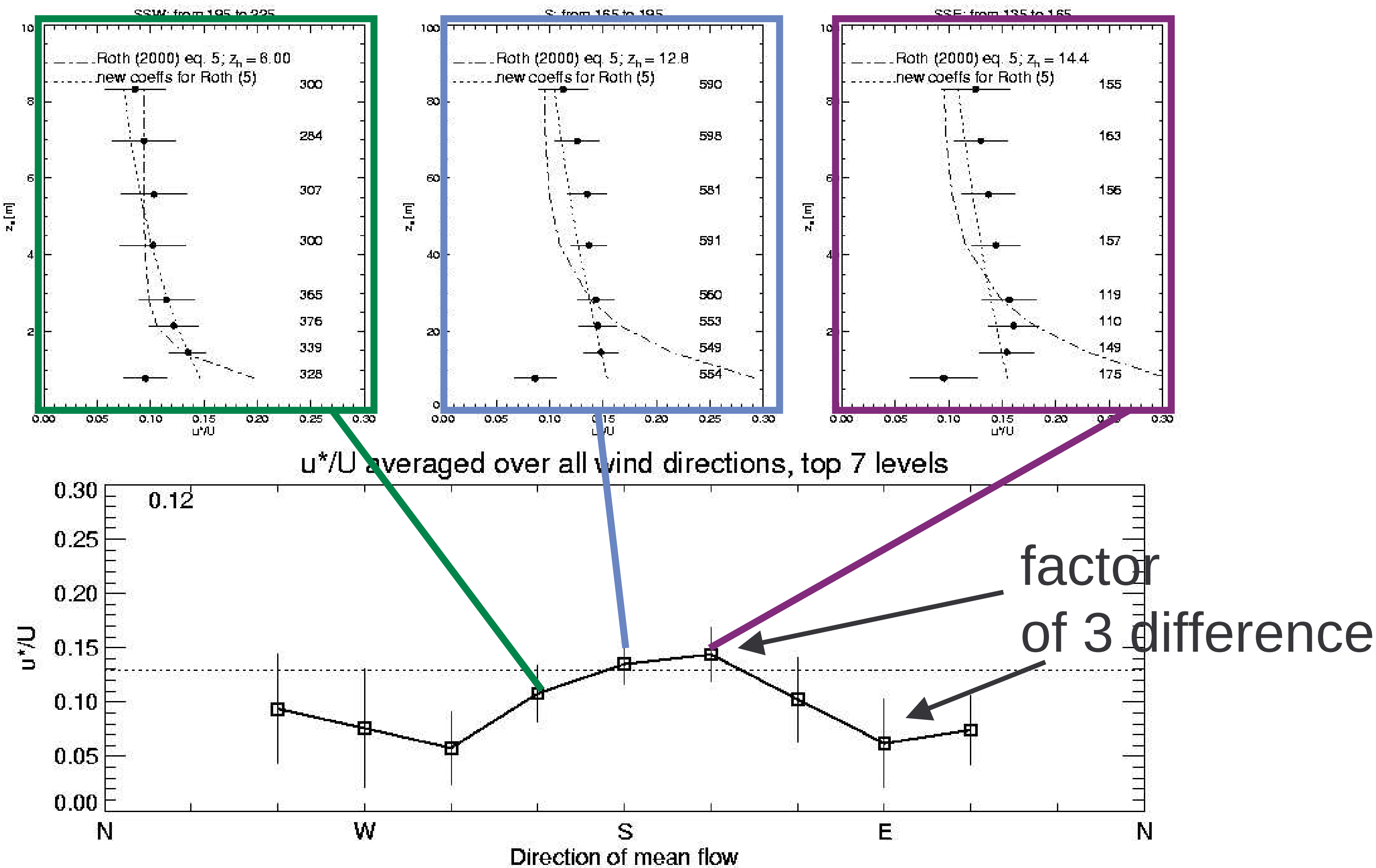
# Friction velocity u* is higher downwind of the central business district




Increased TKE production in central business district due to roughness elements

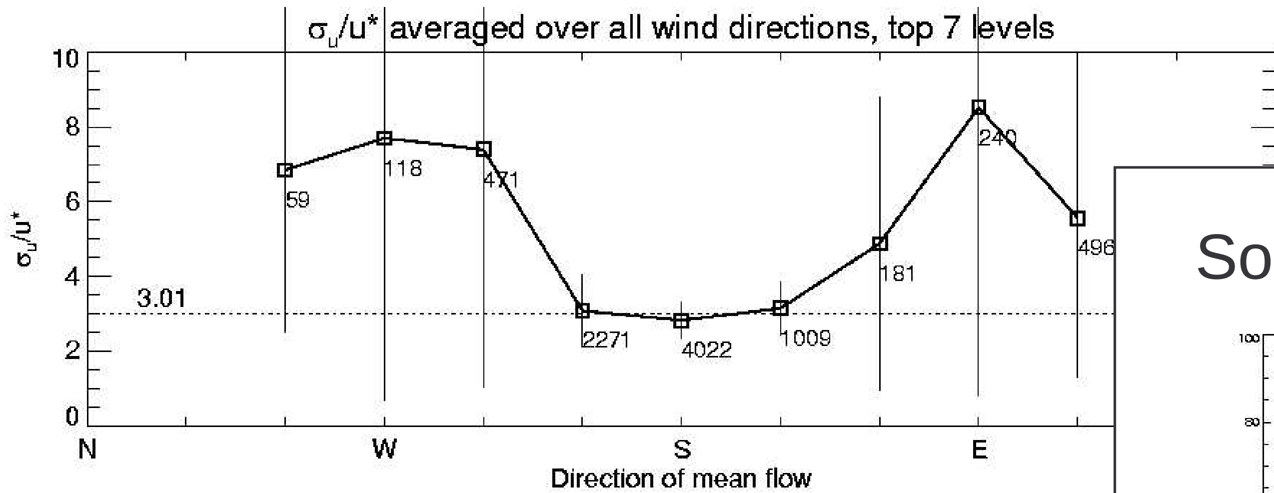
u* profile for southerly flow shows range from 0.4 to 0.6 $ms^{-1}$

# u*/U shows increased TKE production and reduced wind speeds when CBD is upwind.

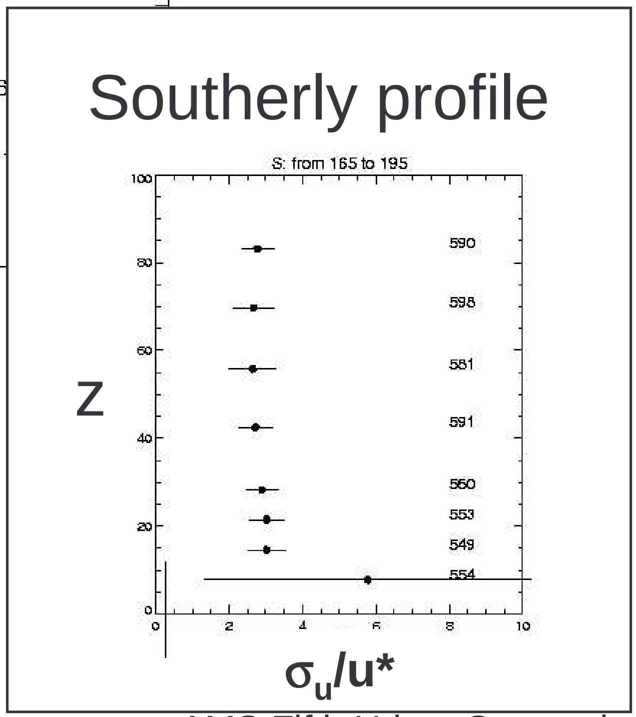


# $\sigma_u/u^*$: mean value for top 7 levels is 3.0

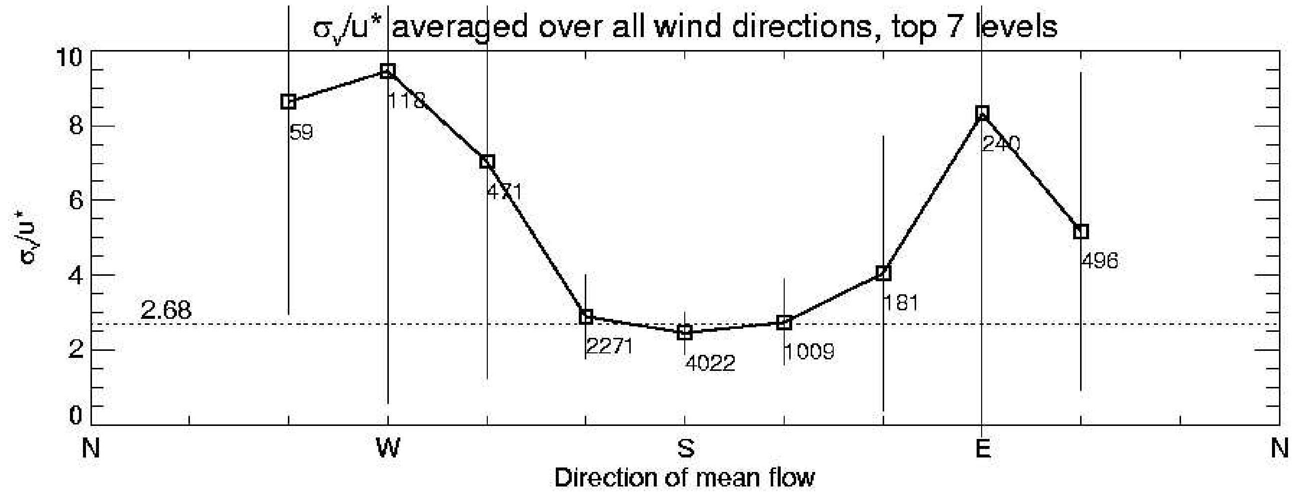
**QWIC-PLUME uses 2.5; Roth (2000 *QJ*) found 2.4; Al-Jiboori (2002 *BLM*) found 1.75.**




Factor of 3 again – variability is due to u*

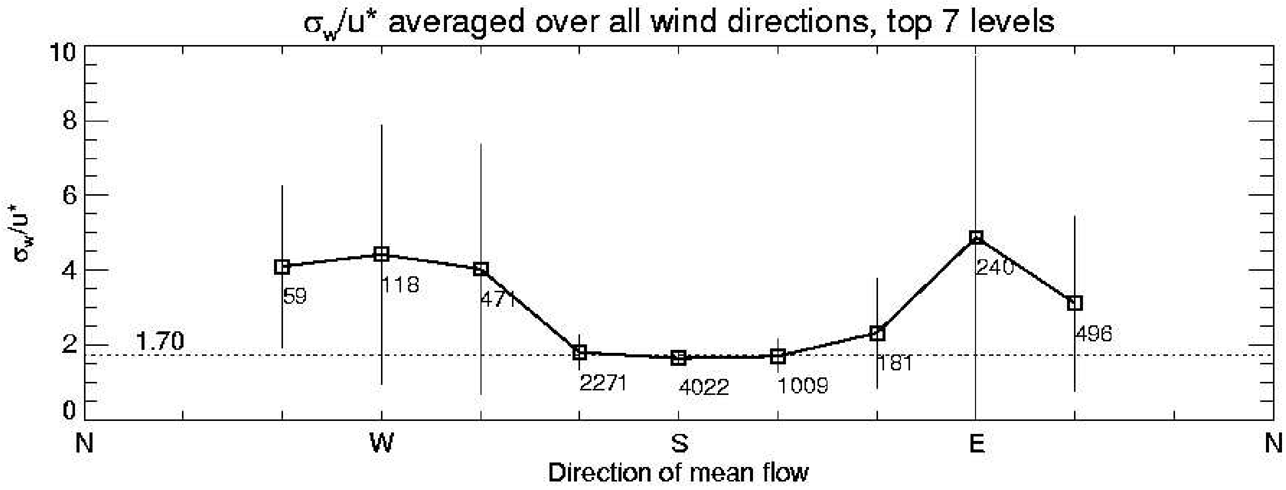


# $\sigma_v/u^*$: mean value for top 7 levels is 2.7




**QWIC-PLUME uses 2.0; Roth (2000 *QJ*) found 1.91; Al-Jiboori (2002 *BLM*) found 1.6.**

# $\sigma_w/u^*$: mean value for top 7 levels is 1.7




**QWIC-PLUME uses 1.3; Roth (2000 *QJ*) found 1.27; Al-Jiboori (2002 *BLM*) found 1.22.**

# Normalized velocity standard deviations: $\sigma_u/u^*$, $\sigma_v/u^*$, and $\sigma_w/u^*$ in neutral conditions

| | | $\sigma_u/u^*$ | $\sigma_v/u^*$ | $\sigma_w/u^*$ |
|---|---|---|---|---|
| Roth (2000): | $z_s/z_H > 0.7$ | **2.40 ± 0.25** | **1.91 ± 0.26** | **1.27 ± 0.26** |
| | $z_s/z_H > 2.5$ | **2.32 ± 0.16** | **1.81 ± 0.20** | **1.25 ± 0.07** |
| | $z_s/z_H < 0.7$ | **2.49 ± 0.30** | **1.99 ± 0.28** | **1.29 ± 0.34** |
| QWIC-PLUME: | | **2.5** | **2.0** | **1.3** |
| Crane: | **Top seven levels, all stabilities** | **3.01** | **2.68** | **1.70** |

…Future work will look at each level independently and quantify any dependence on stability.

## Thus far, we see that:

- Reynolds averaging intervals from 2.5-30 minutes give consistent flux estimates for this dataset
- Neutral stability conditions dominate the dataset
- Turbulence statistics from this dataset are compatible with previous explorations of urban boundary layers

## Upcoming work includes:

- Exploring variability with stability
- Comparison with other measurement systems of JU2003

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